Quantification of Energy Savings from Ireland's Home Energy Saving Scheme: An Ex-Post Billing Analysis.

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Abstract

This paper quantifies the energy savings realised by a sample of participants in the Sustainable Energy Authority of Ireland's (SEAI) Home Energy Saving (HES) residential retrofit scheme, through an ex-post analysis of energy use. The ex-post results obtained through a billing analysis are compared with engineering-type ex-ante savings estimates.

Key characteristics of the sample impacting on energy demand are described and compared to population characteristics in order to give context to the results. An assessment of rebound effects – for example through comfort taking – is made in the context of the sample dwellings.

All dwellings in the study underwent energy efficiency improvements, including insulation upgrades (wall and roof), installation of high-efficiency boilers and/or improved heating controls, as part of the HES scheme. Metered gas and electricity use data for approximately 220 residential dwellings were obtained from meter operators for a baseline period preceding dwelling upgrades. These are compared with post-intervention billing data.

The mean (climate-corrected) reduction in gas demand for the HES sample as a result of energy efficiency upgrades is estimated as 4,064 kWh (22.4%) between 2008 and 2010. Further, a reduction in electricity use of 564 kWh (12.8%) is observed within the sample. The ex-ante engineering calculations of energy saving for the sample dwellings estimated an average reduction of 6,192 kWh. Equating this with the combined gas and electricity reduction estimate, determined on the basis of the billing analysis, suggests a rebound affect of approximately 25%.

The results have potential to inform a broad-scale energy efficiency retrofit programme being undertaken in Ireland from 2011, with the aim of retro-fitting as many as one million residential dwellings by 2020.

Introduction

Background

This paper presents the results of a study seeking to quantify energy savings achieved by participants in the Sustainable Energy Authority of Ireland's (SEAI's) Home Energy Saving scheme (HES).[1] It provides financial support to householders to install a range of technologies to reduce energy demand in homes built before 2006. Technologies supported are comprised of insulation upgrades (wall and roof), high-efficiency boilers and improved heating controls. Typically 30% of the installed costs of measures are grant aided to participants.

The Energy Savings Directive (ESD) (2006/32/EC) stipulates that member states of the European Union (EU) must extend the degree to which they provide ex-post empirical quantification of the impact of their energy-efficiency (EE) policies and measures. Ireland submitted its first National Energy Efficiency Action Plan (NEEAP) to the European authorities in July 2009, outlining the policy measures aimed at reducing energy use by 2020 to 20% below average use in the period 2001–2005

[1] This scheme is administered by SEAI; since this study was undertaken the scheme has been incorporated into the Better Energy Homes scheme (see http://www.seai.ie/grants/).

(Department of Communications, Energy and Natural Resources, 2009). Each of the measures presented in the NEEAP has an *ex-ante* estimate of the associated energy reductions.

These estimates are based predominately on bottom-up calculation methods.[2] Initially, engineering estimated data is used; that is, a calculation to determine a baseline, or the situation *before improvement*, is compared to an *after improvement* calculation, the difference representing the energy savings achieved. Some adjustments are made, on the basis of assumptions, to account for rebound effects such as comfort taking (i.e. increased internal temperatures in households in lieu of energy savings), and to account for any overlap between measures that might affect the same end-users. For a number of policies and programmes measurement of impacts is being undertaken to refine the original savings estimates. Measurement methods include analysis of participants billing data, surveys of scheme participants, third party assessment of savings by energy advisors and programme delivery agents, and installation of energy monitoring devices. This study can contribute to the ex-post quantifications of energy savings due to the HES scheme by:

- Establishing the energy savings associated with a sample of HES scheme participants
- Estimating the rebound effects (potential savings off-set) for the sample

An estimation of the energy savings achieved is made by comparing before-and-after upgrade billing data. A comparison of the sample data is made with gas-use data from a sub-set of the entire population of gas-grid-connected customers in Ireland determined on the basis of similar characteristics thought to impact on energy demand. A range of population characteristics that influence space heating energy demand are considered to give context to the savings estimates.

The study results have the potential to inform a broad-scale energy efficiency retrofit programme being planned for Ireland from 2011 onwards. The retrofit programme seeks to build on the upgrades delivered in over 75,000 homes to date via the HES, with the ultimate aim of retro-fitting as many as one million residential dwellings for improved energy efficiency by 2020.[3]

The *quasi-experimental approach* is most appropriate for the data-set available. It has been used in various observational studies with similar data availability as in the study presented here. Sommerville and Sorrell detail the various methods employed across several studies following this approach (Sommerville & Sorrell, 2007). The *difference in difference* method involves comparing the change in the consumption of participants in an efficiency upgrade scheme with the change in consumption of a cohort of non-participants. The non-participant consumption change over the same period is the counterfactual – what the consumption change would have been in the absence of the application of efficiency measures (Frondel & Schmidt, 2005). This approach has the advantage that differences in the characteristics of the sample and the control group do not impinge on the outcome to the same degree as in simple cross-sectional studies. The behavioural, economic and environmental factors that impact on both the sample and the control group between periods are captured (Frondel & Schmidt, 2005) (Sommerville & Sorrell, 2007) (Sorrell, Dimitropoulos, & Sommerville, 2009). Participants in voluntary efficiency schemes are, by definition, self-selected. This introduces bias into the sample; for example, these participants may already be more aware of their energy consumption than the general population and hence may experience proportionally smaller savings from an efficiency scheme (Sommerville & Sorrell, 2007) (Sorrell, Dimitropoulos, & Sommerville, 2009). Differences in the physical characteristics of the dwellings as well as differences in the demographics and income profiles of the occupants are also likely to result (Hartman, 1988) (Sommerville & Sorrell, 2007). An un-representative sample is likely to have a different average consumption to the population but both may be affected in similar ways by external variables between time periods. If the sample shows similar past

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[2] I.e. estimated energy savings obtained through the implementation of a specific energy-efficiency improvement measure (in kilowatt-hours {kWh}) are added to energy savings results from other specific energy-efficiency improvement measures.
[3]http://www.dcenr.gov.ie/Energy/Energy+Efficiency+and+Affordability+Division/Better+Energy.htm

changes between time periods as the population, then any change in average energy consumption can be hypothesised to be due to the efficiency measures (Frondel & Schmidt, 2005) (Meyer, 1995). Methods can be employed to correct for self-selection bias but are dependent on data availability and as such haven't been employed here (Hartman, 1988).

Section 2 of this paper outlines the method used to evaluate the energy savings, section 3 details the results of the analysis and survey results, and section 4 concludes.

Methodology

To quantify the change in energy usage as a result of the HES upgrades, the change in energy demand of the sample is compared to the change in energy demand of the population. This uses the *difference in difference* method (Frondel & Schmidt, 2005) (Meyer, 1995). The sample is compared to the population over a range of variables that describe both the residents in the dwelling and the dwelling itself. The purpose of this is to ascertain the degree to which expected sample bias is evident (arising from the self-selection present in the sample), and thus to develop a context for interpreting the results.

The change in energy usage of the sample between 2007 and 2008 is compared with the change in usage of the population over the same period. A similar energy usage change suggests that the sample responds to the exogenous variables that relate to energy consumption, e.g. fuel prices and GDP, in a similar way to the population. The change in consumption in the sample cohort between 2008 and 2010 is then compared to that in the population to ascertain if the upgrades have had an impact on the energy use, and if so, to what degree. It should be noted that the years examined in this analysis cover a period with statistically rare economic and climatic events – i.e. a large fall in GDP, large variations in gas and electricity prices, and lower than average winter temperatures.

The following sub-sections outline the characteristics and background of the sample data, identifies the sources of bias, and details the temperature correction and data-cleaning methods for both the sample and the population.

Sample households

In order to obtain accurate billing data for heating fuels, the cohort of HES scheme participants connected to the metered gas grid was considered, and unmetered oil-heated homes were excluded from the study. To ensure sufficient data was available on house type, size, and specific energy characteristics (such as the thermal properties of all dwellings in the study), the sample size was further limited to participants who had undertaken a before-and-after building energy rating (BER). A BER is an indication of the energy performance of a home. It covers energy use for space and water heating, ventilation and lighting, calculated on the basis of standard occupancy and heating patterns.[4]

Over 500 dwellings met these criteria at the time the study was initiated, and correspondence was sent seeking permission from the householders to collect historical energy-use data for their dwellings directly from the gas and electricity meter operators.[5] A total of 250 positive responses were received. Following data-cleaning (described below), a total of 216 households with useful datasets remained.

Table 1 below shows a summary of measures installed in the sample dwellings. Roof insulation, cavity-wall filling and boiler upgrades are the most common measures chosen by the respondents.

[4] See www.seai.ie/ber for more details.

[5] Bord Gáis Networks operates the Gas Point Registration Operator (GPRO) function on behalf of Gaslink. ESB Networks operates the Meter Registration System Operator (MRSO), with responsibility for the processing/aggregation of electricity meter data.

Table 1. Efficiency upgrades undertaken in the sample

Measure	Frequency
Roof insulation	152
Cavity wall	101
Dry-lining	34
External insulation	15
Heating controls upgrade only	20
High-efficiency gas boiler with heating controls upgrade	87
Total dwellings	216
Measures per dwelling	1.9

Supplementary data and analysis

Several data sources in addition to the gas and electricity use data are combined to construct a fuller characterisation of the sample.

Details of occupancy and behaviour (such as the use of secondary heating sources including plug-in electric heaters) were gathered from the sample by way of a postal survey (*HES sample survey*). A separate survey of HES scheme participants (‘*Bringing Energy Home (BEH)’* survey) had over nine thousand respondents, three thousand of whom use gas as their primary fuel (SEAI, 2010). This survey has details of occupation, income levels, age of primary household member and occupancy for scheme participants.

The HES sample and BEH survey data are compared to population for the variables outlined in table 2 below. This table also indicates the data source and the compatibility checks applied. The relevant statistical tests are applied to determine compatibility.

Table 2. Detail of data sources and compatibility checks applied

Variable	250 HES survey data source	BEH compatibility check	Population compatibility check
Occupancy	250 HES Survey	-	Energy in the Residential Sector
Occupation of home owner	-	Bringing Energy Home	National Household Survey
Period of construction (dwelling age)	BER	Bringing Energy Home	Energy in the Residential Sector
Floor area	BER	BER	Energy in the Residential Sector
Change in energy use 2007-2008	250 HES survey	-	Population gas consumption data

Population data for these variables are taken from SEAI’s Energy in the Residential Sector report for the dwelling details (SEAI EPSSU , 2008) and from the Quarterly National Household Survey for the homeowner characteristics (Central Statistics Office, 2010). A similar trend in the change in energy use between 2007 and 2008 suggests that the sample responds to changes in exogenous variables in a similar manner to the population. The period 2007–2008 was chosen as these are the most recent years prior to the sample receiving energy efficiency upgrades. The use of recent years reduces the probability of variance in other variables such as occupancy or economic status.

Sample bias

Since the sample was not selected on a random basis, consideration is given to the potential bias of the sample in order to give context to comparisons with the broader population of existing dwellings in Ireland.

The HES Scheme is open to all householders with dwellings built before 2006. Participants must produce some up-front capital; generally around 70% of the cost of measures installed. This potentially rules out low-income households from the scheme entirely.[6] Hence the sample is likely to include those that can afford sufficient energy to comfortably heat their homes, and for which fuel costs may represent a smaller proportion of their total expenditure compared to fuel-poor groups.

While there has been widespread advertising of the HES scheme, the BEH survey suggests that the socio-economic profile of participants is not directly correlated with that of the population (SEAI, 2010). For example, while participants' incomes are somewhat representative of national patterns, low participation rates of single adults and high participation rates of retired householders have been observed. Demographic characteristics of a household such as age profile, home ownership and employment status are contributing factors to variations in energy demand per dwelling.

The sample includes only participants who opted voluntarily for a before-and-after BER, for which there was a small additional fee. This might indicate that sample householders had a specific interest in the impact of the planned upgrades on their asset rating (BER).[7] On this basis, sample householders may have been more aware of their energy use prior to scheme participation, compared with participants who were not interested in the BER before or after an upgrade.

In order that metered billing data could be obtained, dwellings that use heating fuels other than gas were excluded. Comparison of average dwelling fuel-use data suggests that gas customers use less kWh per annum than those who use oil, the other dominant main heating source in Ireland (further detail is provided below). Given that oil-heated homes tend to be larger and more often located in rural areas compared to gas-grid-connected dwellings, the per measure savings could be higher for this cohort of dwellings.

Population gas consumption data

Bord Gáis Energy granted SEAI access to anonymised annual per dwelling gas consumption data from 1990 to 2010. This contains information on the year of connection of the dwelling to the gas grid, if there was a change in consumer in a given year and, for some data points, the type of house. From this data, annual consumption for 2007, 2008, 2009 and 2010 was extracted.

Data cleaning

The initial step in data-cleaning removed houses connected to the grid after 2006 from the population gas consumption data so as to align the data with the HES sample which, by the terms of the scheme, includes only dwellings built pre-2006. Both the sample and the population were then cleaned, using the following method.

Households with annual consumption of less than 575 kWh[8] were removed to account for households that use gas exclusively for cooking. This also captured data points with low or negative

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[6] These members of society are addressed separately through the Warmer Homes scheme designed specifically for this cohort http://www.seai.ie/Grants/Warmer_Homes_Scheme/.

[7] An alternative might be that the BER was undertaken as required for future sale of the subject household.

[8] Based on BRE Domestic Energy Fact File 2008, Tables 25 and 26 http://www.bre.co.uk/filelibrary/pdf/rpts/Fact_File_2008.pdf

readings as a result of between-year reconciliation of actual meter reads and previous consumption estimation. Dwellings identified as showing a change in account-holder across in any of the years 2007–2010 were removed to minimise variation in demand due to changes in occupancy across the time periods. This was achieved in the sample by removing data points with very low consumption, suggesting a vacant house, or with large changes in year-on-year consumption, suggesting a change in occupancy, or increase in floor area.

In addition, outliers were removed from the population on the basis of an upper limit set at 1.5 times the inter-quartile range for each year (between 32,000 and 36,000 kWh/y depending on the year). The final population size for each year is equal to 190,000[9] and the HES sample was reduced from 250 to 216 data-sets. Following the data-cleaning, both the sample and the population were considered to have normal distributions.

Impact Estimation

The gas consumption data is based on actual meter readings and estimates (typically bi-monthly) and is aggregated on an annual basis. The heating component (70%) of consumption data is normalised (weather-corrected) to account for temperature differences between years (degree day data from Eurostat) (Energy Savings Trust, 2004).

The change in consumption between 2007 and 2008 for the sample is compared to that of the population for the same period. These years represent the most recent data available prior to efficiency upgrades and are chosen to limit the probability of changes to explanatory variables in the post-upgrade data. The fact that there is no statistical difference in the consumption change between the sample and the population over these years indicates that the sample is a suitable proxy for estimating savings after efficiency upgrades.

A baseline energy use was established for the survey sample to estimate what their energy usage might have been if they had not had efficiency upgrades. This baseline usage is assumed to be the same as that of the population. This assumption is justified in two ways; first, the energy usage of the sample is compared to the population for two pre-upgrade years (as described above); secondly, the sample is compared to the population for statistical similarities over a range of variables previously identified as being important influences on gas demand (Frondel & Schmidt, 2005) (Sorrell, Dimitropoulos, & Sommerville, 2009). In addition, this process identifies bias in the sample as a result of self-selection (described above).

The difference between population and sample data for the full year 2010 is taken as the impact of the upgrade measures, all other effects assumed to be equal. The potential impact of sample bias is then considered qualitatively.

Rebound effects

While the effects of comfort taking and non-compliance with building specifications for installed improvements cannot be separated as part of this study, an estimate is made of their combined impact, together with any error in the ex-ante engineering-based estimate. To determine the rebound effect, the difference between the average ex-ante estimate of savings is compared to the average measured savings. Engineering estimates are based on the methodology used in the Dwelling Energy Assessment Procedure (DEAP) software used to generate Building Energy Ratings (BERs) for dwellings in Ireland.[10] The savings are applied on a unitary savings per measure basis for three dwelling types, as outlined in Table 3.

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[9] Due to the anonymised nature of the population data it was not possible to eliminate all HES scheme participants from this data. It is estimated that around 5% of the dwellings remaining in the population data underwent upgrades via HES, and that any deflationary effect on energy demand of the trimmed population data for 2009/2010 is minimal.

[10] See http://www.seai.ie/Your_Building/BER/BER_Assessors/Technical/DEAP/

Table 3. Unitary savings estimates

	2 bed apartment (75m2)	3 bed semi (110m2)	3-4 bed detached (140m2)
Cavity wall insulation	1,375	2,200	2,800
Internal dry-lining	2,500	5,500	7,000
External wall insulation	3,000	6,000	7,500
Heating controls upgrade	2,750	4,400	5,600
Heating controls upgrade plus high efficiency boiler (>90%)	5,150	7,500	9,000
Roof/attic insulation	800	1,500	1,800

Results

Sample and population comparisons

Table 4 below provides a summary of annual mean gas demand (climate-corrected) for the sample and population sub-set, together with residential gas prices and GDP for the years in question. . Energy consumption can be expected to increase with a fall in fuel price but can be expected to fall with a fall GDP. It is evident that the mean demand of the sample and population sub-set falls over the period with the exception of 2010 for the sample data. In this case, despite the price decrease in 2009/2010, mean consumption in the sample decreased.

Table 4. Average consumption and macroeconomic variables 2007-2010

	2007	2008	2009	2010
Sample (kWh/annum)	17,552	18,167	15,507	13,811
Population (kWh/annum)	16,259	16,679	15,423	15,766
Gas price €/GJ (source: Eurostat)	14.74	13.29	15.76	12.07
GDP (% change on previous year)	5.6	-3.5	-7.6	-1.0

The average space heating demand for residential dwellings in Ireland (including both gas and oil heated dwellings) in 2006 was 19,713 kWh (SEAI EPSSU , 2008). The population average for gas heated dwellings of 16,289 kWh for the same year suggests that the approx. 45% of oil-heated dwellings in the country use more energy for space heating than the average dwelling.

Gas demand changes – sample and population

The change in average gas demand of both the sample and the population data (cleaned as described above) are analysed in Table 5 below.

The results indicate that the change in the sample and population mean energy demand before sample upgrades (2008 v. 2007) data is not significantly different. The sample mean is statistically higher than the population mean in 2008, but the change in energy use between 2007 and 2008 in both the sample and the population is statistically the same. This demonstrates that although the sample has a higher overall consumption in 2008, both the sample and the population are influenced by external price and macroeconomic variables in a similar manner in these years.

Table 5. Pre- and post-upgrade mean demand variation analysis

	Δ mean (climate corrected)	**n**	**t**	**p**
Sample 2007/2008	620	216	0.95	0.341
Population 2007/2008	420			
Sample 2008/2010	-4,356	216	11.08	0.000
Population 2008/2010	-913			

On the basis of these results, the assumption holds that the impacts of both fuel price and GDP fluctuation affect the sample and population in the same way in 2007/2008. Further, a significant variation in reduction in demand of the sample and population is observed between 2008 and 2010. It is assumed that this reduction is due to the energy efficiency improvements of the sample, all other things being equal.

The net reduction in demand for the population (913kWh) from 2008 to 2010 represents a 5.5% reduction in average demand of population dwellings. When this is applied to the reduction observed in sample dwellings (4,356 kWh), a net reduction of 22.4% (4,064 kWh) per annum is estimated.

Electricity demand reductions in the sample

In addition to reductions in gas demand, survey responses from the sample dwellings indicated a reduction in use of secondary heating sources such as plug-in electric heaters.

An analysis of historical electricity bills of the HES sample indicates that consumption for this sample is 564 kWh less than the average electricity consumption of the population of dwellings in 2010. In the absence of disaggregated population data for electricity use for the baseline years (2007/2008), it is not possible at this stage to draw a direct conclusion that this reduction is caused entirely by the HES scheme.

Rebound effects

Ex-ante engineering estimates of savings per installed measure suggested an average saving per dwelling of 6,192 kWh. This is higher than the mean reduction in gas demand. However, when taken together with the mean electricity reduction, there is a difference of 1,564 kWh (or approx. 25% of the engineering savings). Given the non-random nature of the sample and the resultant uncertainty about the impacts of extraneous factors in demand to the energy efficiency upgrades, this does not represent a definitive estimate of rebound effects. However, it does provide some new guidance to the level of adjustment required to more closely align current engineering estimates with actual measured savings for the cohort of scheme participants using gas as a main source of heating for example.

Identifying sample bias

To enable further comparison between population data, it was necessary to compare (statistically) the sample data to data for the entire population across a range of factors that affect gas demand. The fields chosen (on the basis of available data) were: dwelling age (period of construction), dwelling floor area, dwelling type, per dwelling occupancy levels, and occupation of homeowner. The statistical tests to determine the compatibility of the various sample data sources with the HES survey data and the Bringing Energy Home (BEH) respondents are summarised below; the assumption of normality applies and results are determined at a significance level of 5%.

Dwelling characteristics

Figure 1 shows the relative frequency distribution for the period of dwelling construction for the HES sample, the BEH respondents and the population of dwellings built before the end of 2006. A chi-squared test indicates that the HES sample is significantly different to both the BEH sample and the population in terms of the profile of dwelling ages (see Table 6). This is due in particular to the variation in frequency in the pre-1919, 1961-1970 and 2001-2006 cohorts. The degree and nature of the impact on savings estimates of this parameter requires further investigation.

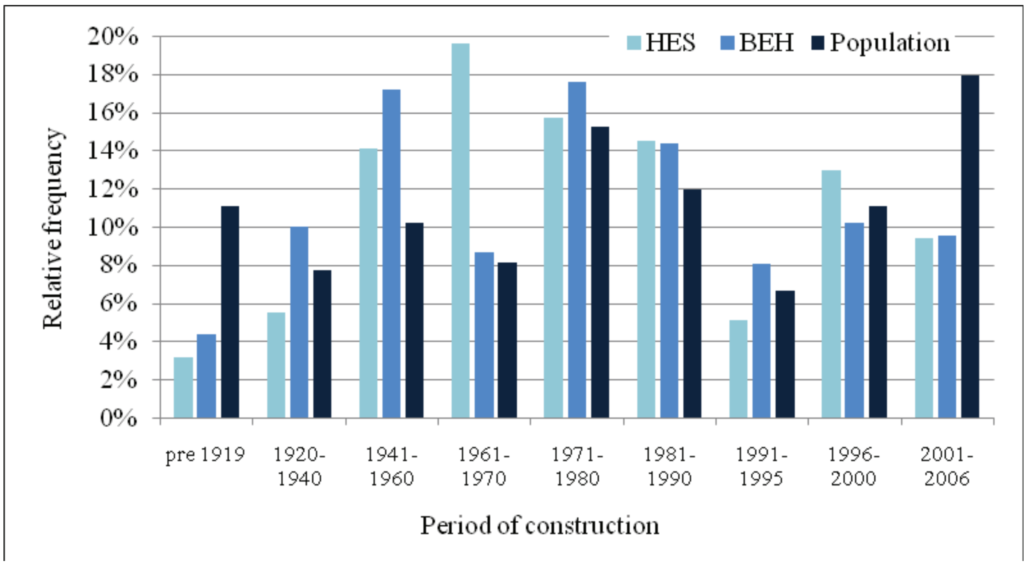

Figure 1. Period of dwelling construction

Table 6. Chi-squared results - period of construction

	BEH v HES sample	Population v HES sample
Chi-squared	47	75
df	8	8
p	0.00	0.00

The mean floor areas for the HES sample dwellings, the BEH dwellings and the population are not significantly different (Table 7).

Table 7. Comparison of floor areas

	Mean floor areas compared (m^2)		
HES sample	120.0	120.0	
Population	117.0		117.0
BEH sample		119.0	119.0
t	1.15	0.26	0.80
p	0.25	0.80	0.42

Dwelling type

While the HES and BEH sample data bear some statistical resemblance, both samples differ from the population in terms of dwelling type (Figure 2).

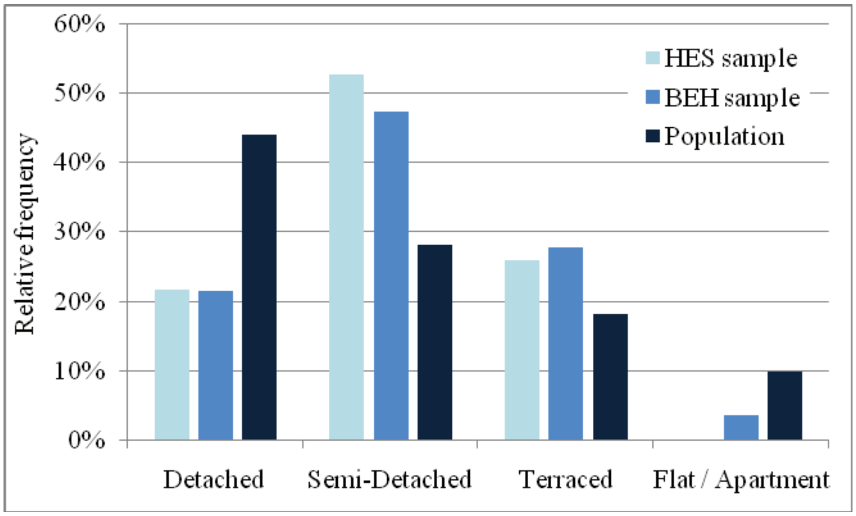

Figure 2. Dwelling type

Table 8. Chi-squared test results – dwelling type

	Population v BEH	HES v BEH	Population v HES
Chi-squared	134	8	89
df	8	8	8
p	0.000	0.081	0.000

Homeowner characteristics

Comparisons of occupancy (numbers of occupants per dwelling) for the HES sample, the BEH sample and the population, and on the basis of electoral districts, all indicate significant differences (Table 9).

Table 9. Comparison of Occupancy Levels

	Occupancy (shared samples compared)		
HES sample	2.5	2.5	2.5
Population	2.8		
BEH sample		2.9	
Electoral district			2.7
t	3.46	4.19	2.47
p	0.001	0.000	0.014

In general, in the population there is a higher proportion of unemployed and a lower proportion working compared to both the BEH and HES samples (Figure 3). A chi-squared test for differences in occupation categories indicates statistically significant differences between the HES (data inferred from electoral district data) and BEH samples and the population. Further investigation into the impact of occupation on energy demand is needed.

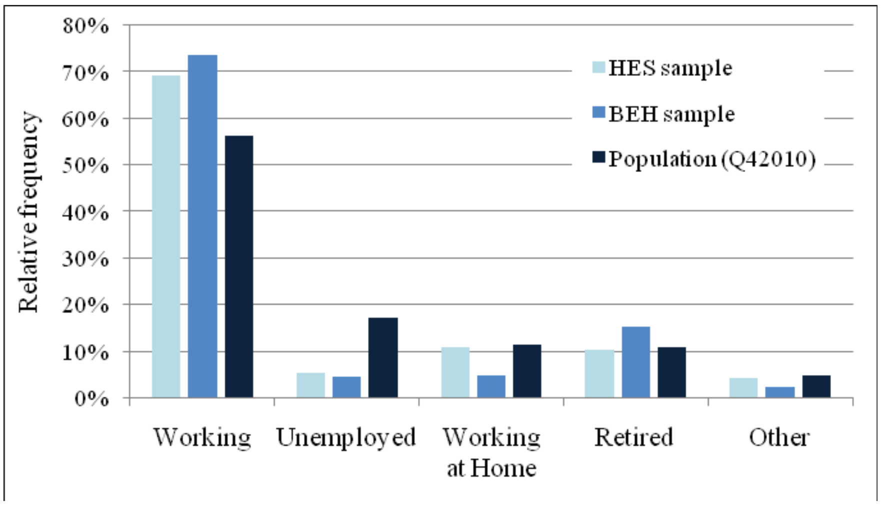

Figure 3. Homeowner occupation

Table 10. Chi-squared test results - occupation category

	BEH v HES	Population v BEH
Chi-squared	239.2	691.1
df	8	8
p	0.000	0.000

Conclusion

The mean (climate-corrected) reduction in gas demand for the HES sample as a result of energy efficiency upgrades is estimated as 4,064 kWh, or 22.4%, between 2008 and 2010. Further, a reduction of electricity demand of 564 kWh (12.8%) is observed within the sample. Ex-ante engineering calculations of energy saving for the sample dwellings estimate an average reduction of 6,192 kWh. Equating this with the combined gas and electricity reduction estimate, determined on the basis of the billing analysis, suggests a rebound affect of approximately 25%.

Given the statistical differences between the sample and the population for dwelling and occupant characteristics that affect energy demand, it is not possible to draw conclusions that can be applied to the population of dwellings in Ireland with the potential for energy efficiency improvements. The results do, however, verify that substantial energy savings (>20% per dwelling) are being realised through the scheme. In addition to energy savings, surveys of HES participants indicated a range of other benefits realised as a result of energy efficiency upgrades, including: wellbeing, improved internal climate (increased comfort, reduced dampness), and perceived increase in the value of dwellings.

Given the non-random nature of the sample and based on the tests outlined above, it is clear that the sample is not fully representative of the population as a whole. This weakens the assumption that the sample is affected by external variables in the same way as the population. This limits these specific findings to the impacts on energy demand for energy consumers with similar characteristics (dwelling and homeowner) to those of the sample analysed. The age profile and occupancy characteristics of the sample householders might suggest an underestimate of savings available in the wider population of pre-2006 dwellings, while the relative age of dwelling in the sample and population might indicate an overestimate. Further, given that the study was limited to gas heated homes; overall savings per dwelling of the sample might represent an underestimate of savings available in typically larger oil heated homes. Further work is required to determine the order of magnitude of these aspects on estimates of per dwelling savings before estimates of the potential from a broad scale rollout of measures supported by the scheme can be made.

A statistically significant sample, representative of dwellings in Ireland that have undergone an upgrade through HES, could be more usefully compared to a control group of dwellings that had not undergone an upgrade. Such a study could provide sufficient data to assess the overall potential for improvement in Ireland's dwelling stock for a given suite of technologies.

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